Belitsi

Archaeological Background

Belitsi magoula is a recently discovered prehistoric site, because of the public works construction for the enlargement of the National Road (1999–2000). It is a relatively high magoula which was inhabited at least during Early and Middle Neolithic period. Archaeological excavations revealed fragmentary ruins of buildings with walls constructed using mudbrick or wooden frames covered with clay.

The key location of the site at the northwest side of the Almyros plain, where the natural passage from the coastal plain to the inner plain of Farsala and Western Thessaly begins, attaches particular importance to the settlement.

The magoula lies among level agricultural terrain that rises gradually from west to east. The landscape is pocketed by many rivers and stream beds. The National Road passes only a few hundred meters away from the prehistoric site, while the village of Mikrothivai is 1.5 km toward the east. The rest of the area is sparsely pocketed by farm installations. The large rectangular foundations of a high security prison (construction abandoned) lies only 500 m towards the west. Most cultivated land appears to be wheat with some olive orchards. Land use including field boundaries is little changed since 1960 with the exception of the National Road. The highway system and its interchange appear in the 1973 aerial photograph, but not in the one from 1960. Elevations around the target range from 95-105 masl.

Satellite Remote Sensing and Historical Aerial Photography Survey

A Quickbird image from 15 June 2009 was used for satellite remote sensing at Belitsi (Figure 1). This satellite image has an off-nadir angle of 8.9° and a ground sampling distance (GSD) of 0.63 m (panchromatic) and 2.50 m (multispectral). In addition to the satellite imagery, two aerial photographs were used for analysis: (1) 12 October 1960 with a scale of 1:15,000; (2) 1973 (exact date unknown) with a scale of 1:15,000 (Figure 2).

Remote sensing around Belitsi produced a number of anomalies (Figures 3-4). The majority of them are from palaeochannels. In fact, the historical aerial photographs document the paleoenvironment of the region better than the satellite imagery. Rivers and streams appear to have been plentiful immediately west of the habitation mound at a distance of less than 100 m (Figure 5). The 1960 and 1972 aerial photographs both document this, while the satellite imagery shows the wider path of the hydrological activity. Water likely impacted the settlement toward the west in an area where geophysics was limited due to the olive tree cultivation. The magoula is best documented in the 1960 aerial photograph by a circular formation nearly 100 m in diameter (see Figure 5). This anomaly is probably from the habitation mound, although it could also be caused by hydrological activity. A potential interesting surface anomaly is anomaly #40, which is some 650 m east of Belitsi (Figure 6). There is a clear feature here of circular proportions measuring around 90 m in diameter. The boundaries are somewhat fuzzy, but the extent of vegetation stress and soil marks in RBG pansharp images and a host of spectral filters, e.g. PCA and Decorrelation Stretch, leave little doubt of this feature’s presence.

Figure 1: Belitsi from a 15 June 2009 Quickbird image

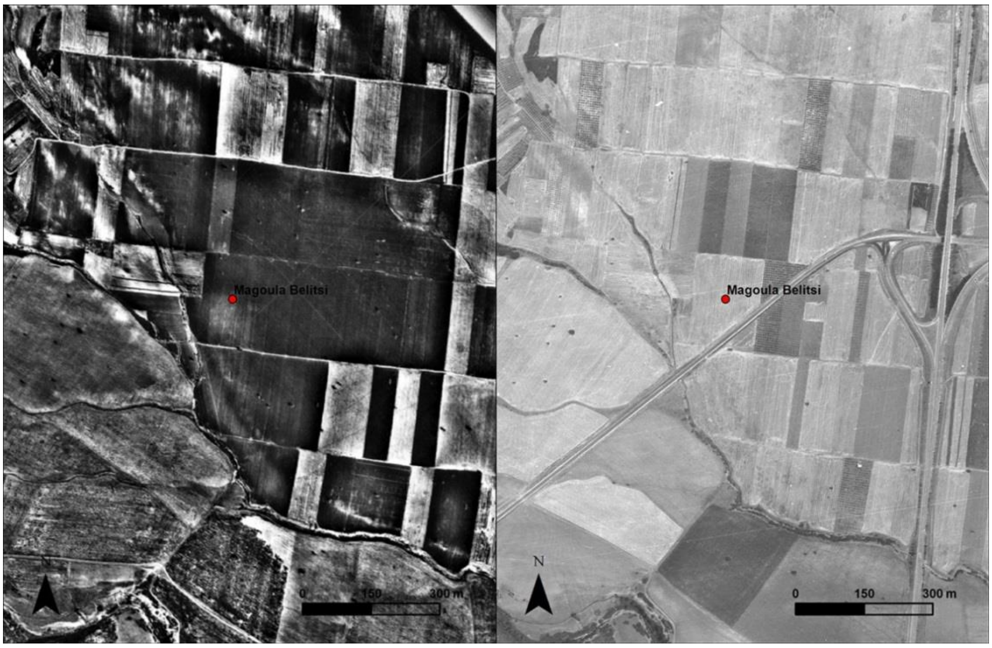


Figure 2: Belitsi from aerial photographs taken 12 October 1960 (left), and 1973 (right)

Figure 3: Surface anomalies from the 15 June 2009 Quickbird image within a 1 km radius around Belitsi

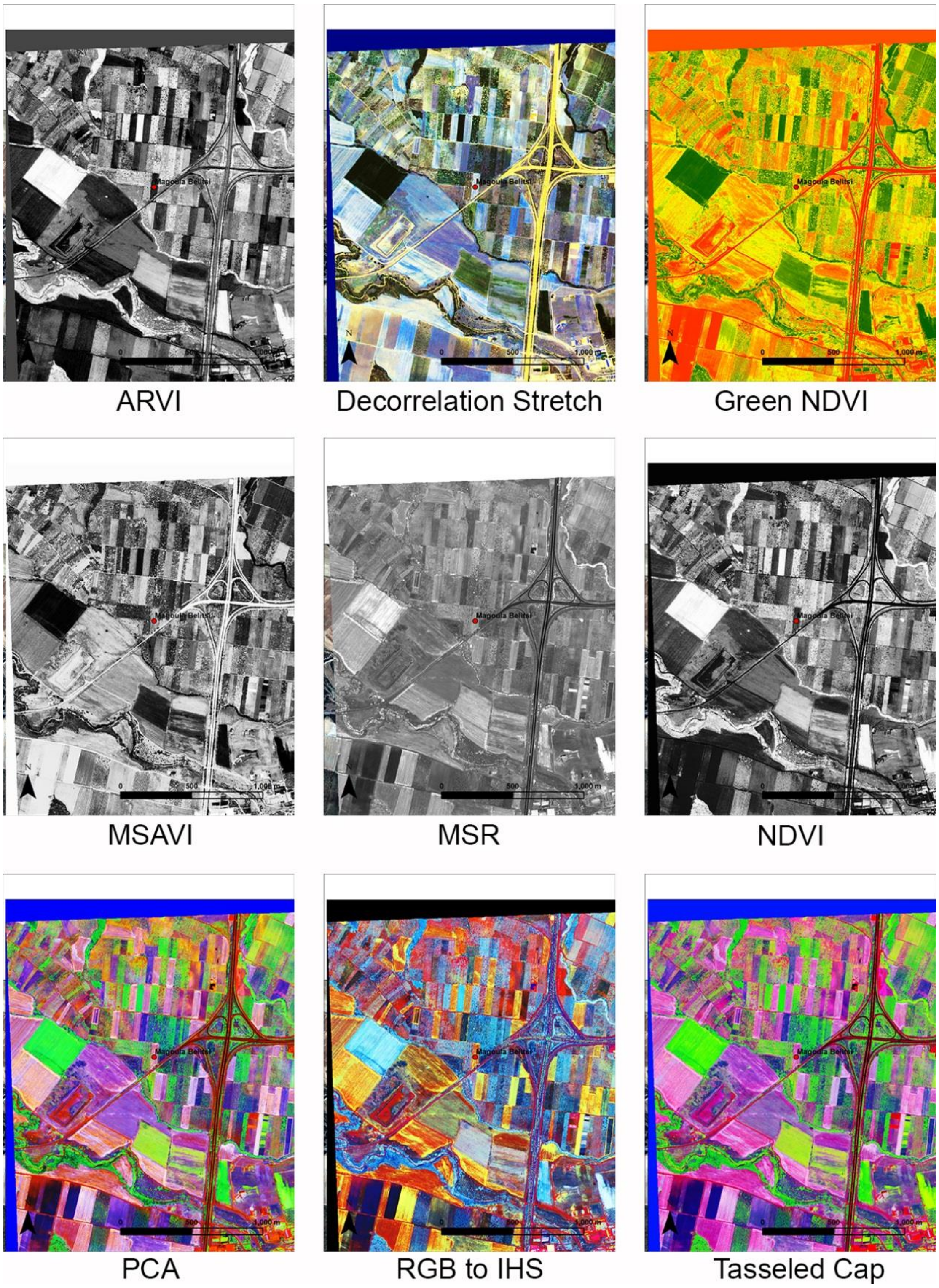


Figure 4: Spectral filters and vegetation indices applied to the 15 June 2009 Quickbird image around Belitsi.

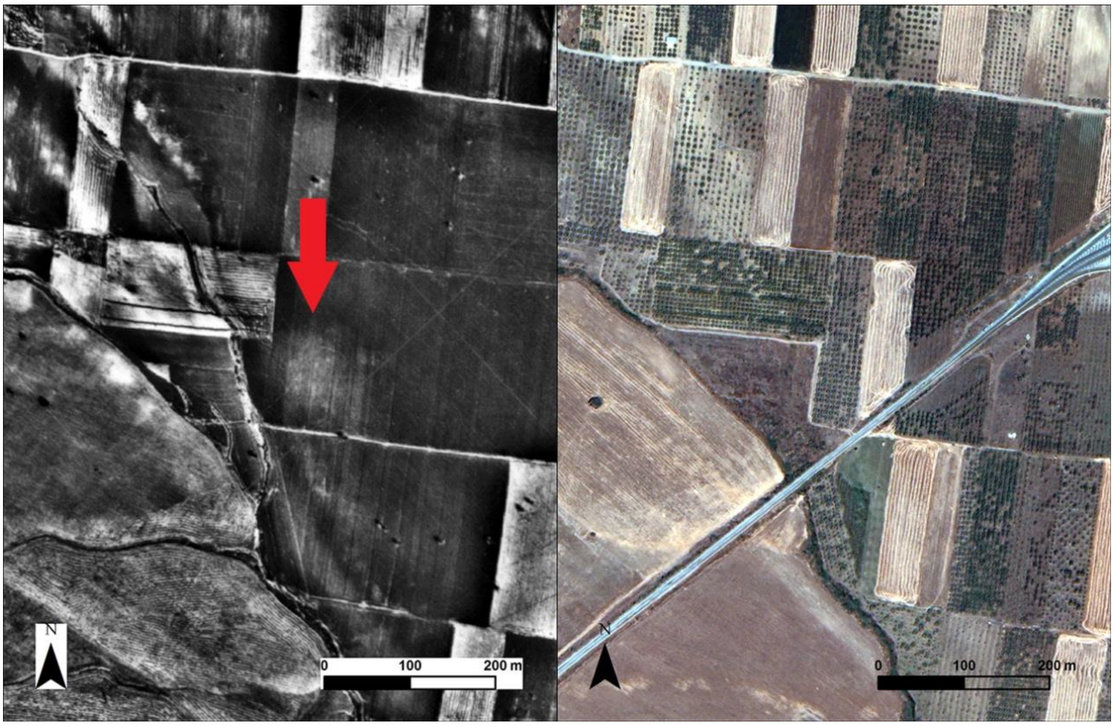


Figure 5: Palaeochannels and a circular anomaly from the magoula (red arrow) in the 12 October 1960 aerial photograph (left). Some palaeochannels are visible in the 15 June 2009 Quickbird image (right), but nothing from the magoula.

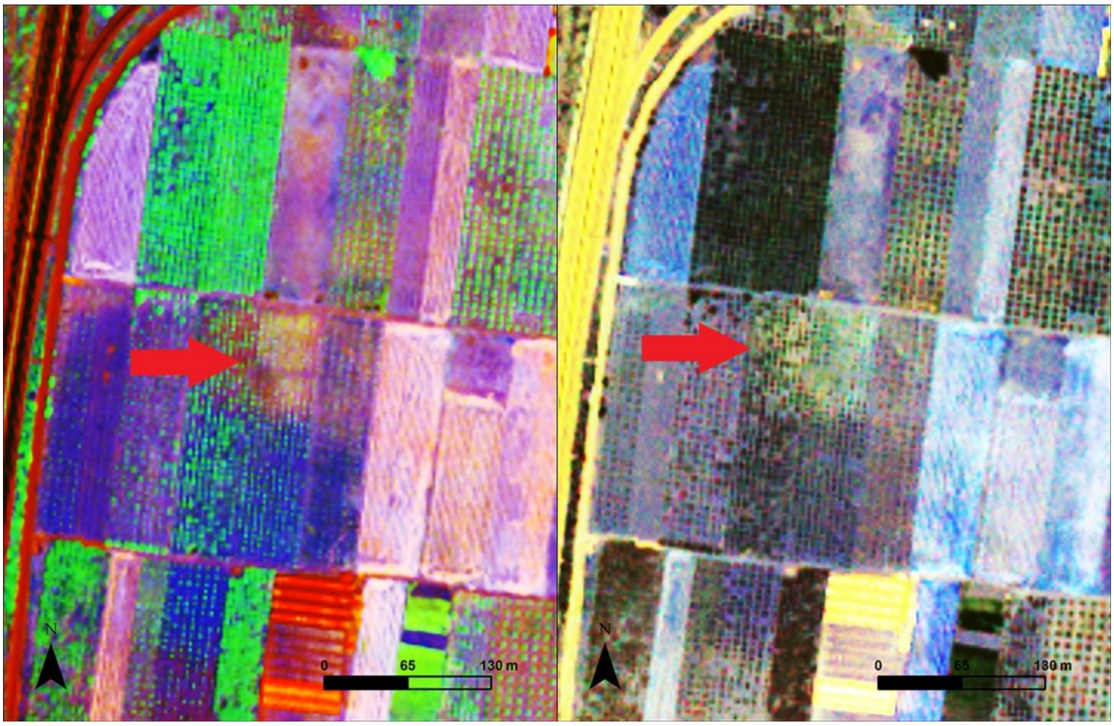


Figure 6: Anomaly #40 from PCA (left), and Decorrelation Stretch (right)

Remotely Piloted Aircraft Systems (RPAS) Survey

Figure 7: RPAS data from Belitsi

Belitsi was surveyed with RPAS on November 2013 (Figure 7). The magoula lies among modern field plots with predominately northeast to southwest orientations. Furthermore, the area is crossed by an access road leading to the National Road, which has impacted part of the original elevation. Despite the difficulties of reading the generated orthophotos for the site (with a coverage of about 12 hectares in total), the digital model (Figure 8) produced through photogrammetric processing provides some clues on the micro-topography of the area, contributing to identify the highest hill-top in the surveyed area. Although the final resolution of the photogrammetric processing of the RPAS images could be considered as satisfactory, the presence of olive groves and recently harvested fields does not allow any further photo-interpretation.

Figure 8: Contour lines (0.5 meter interval) generated from the photogrammetric digital terrain model.

Geophysical Prospection

Geomagnetic Survey

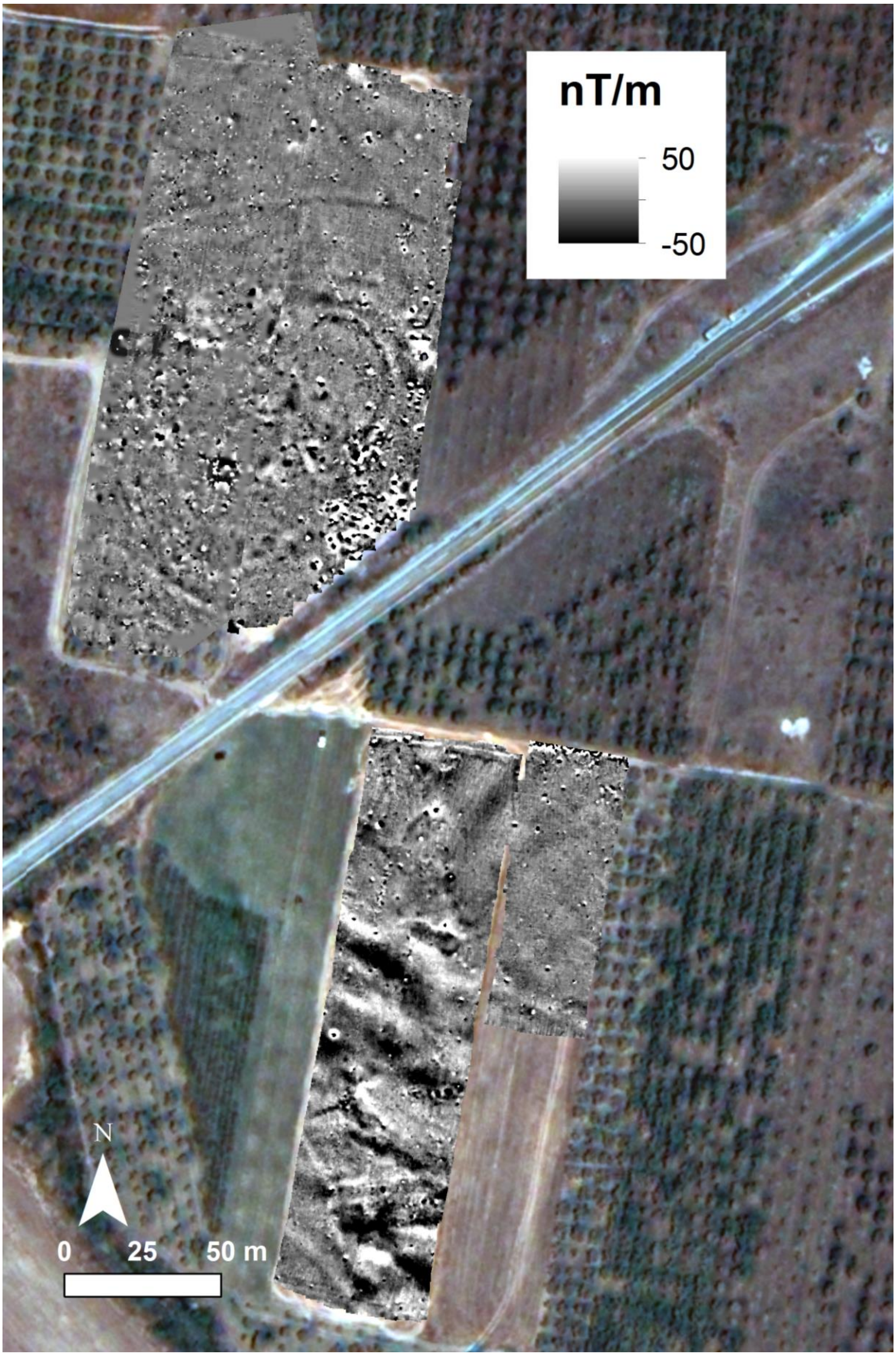


Figure 9: Geomagnetic results from Belitsi.

Geomagnetic survey at Magoula Belitsi covered an area with dense olive trees (Figure 9). The sensor array was run in between trees and voids were filled with interpolation. Therefore, the interpretation of the measurements has been affected from this configuration of data. The area was also littered with modern agricultural elements so that there is a considerable number of a dipolar reading in the survey area. One final issue in the area is related to weather conditions. The survey was performed on a rainy day and the magnetic soil affected readings in a cyclical manner; as the wheels moved along a transect, the mud which was stuck in between wheels altered readings periodically. This effect is the most visible to the north of the study area.

Despite these problems, geomagnetic data reveals some information on settlement characteristics. Even though there is no clear evidence for architectural structures, ditches, or walls, the central portions of the survey area is magnetically busier than neighboring northern and southern sections. In fact, a number of linear anomalies with high magnetic readings delineate this area. Furthermore, this relatively bounded area merges well with the results from the electromagnetic survey.

Electromagnetic Induction Survey

Electrical conductivity does not show clear information related to the archaeological features. It shows general variation probably induced by geological and sedimentary material. On the northern part of the tell, a ditch appears in the data which probably defines a boundary of the Neolithic settlement. Inside the tell, data are more resistive. This could be explained by more silty soils induced by anthropogenic material. Nevertheless electrical conductivity does not show any clear archaeological features (Figure 10).

Magnetic susceptibility is clearer (Figure 11). A magnetic belt, 20 m wide, encircles the northern part of the magoula. Comparing the map of magnetic susceptibility with magnetic anomalies, one can see that this area is less noisy than the highest part of the magoula. The high susceptibility could decrease the contrast between soil and archaeological remains, which results in less magnetic anomalies.

As for magnetic anomalies, the upper part of the magoula shows a lot of small magnetic anomalies but without specific spatial organization. We can expect some delimitation of magnetic area but not more like building. The highest anomalies could be kilns or domestic hearths.

The other survey area is located to the south. There are no visible geophysical anomalies (magnetic anomalies, electrical conductivity anomalies, magnetic susceptibility anomalies) which could be related to architectural features. The area is also more homogenous when compared to the first survey area, suggesting the settlement did not extend to the southeast. Nevertheless, anomalies most probably of geological origin run in northwest-southeast directions.

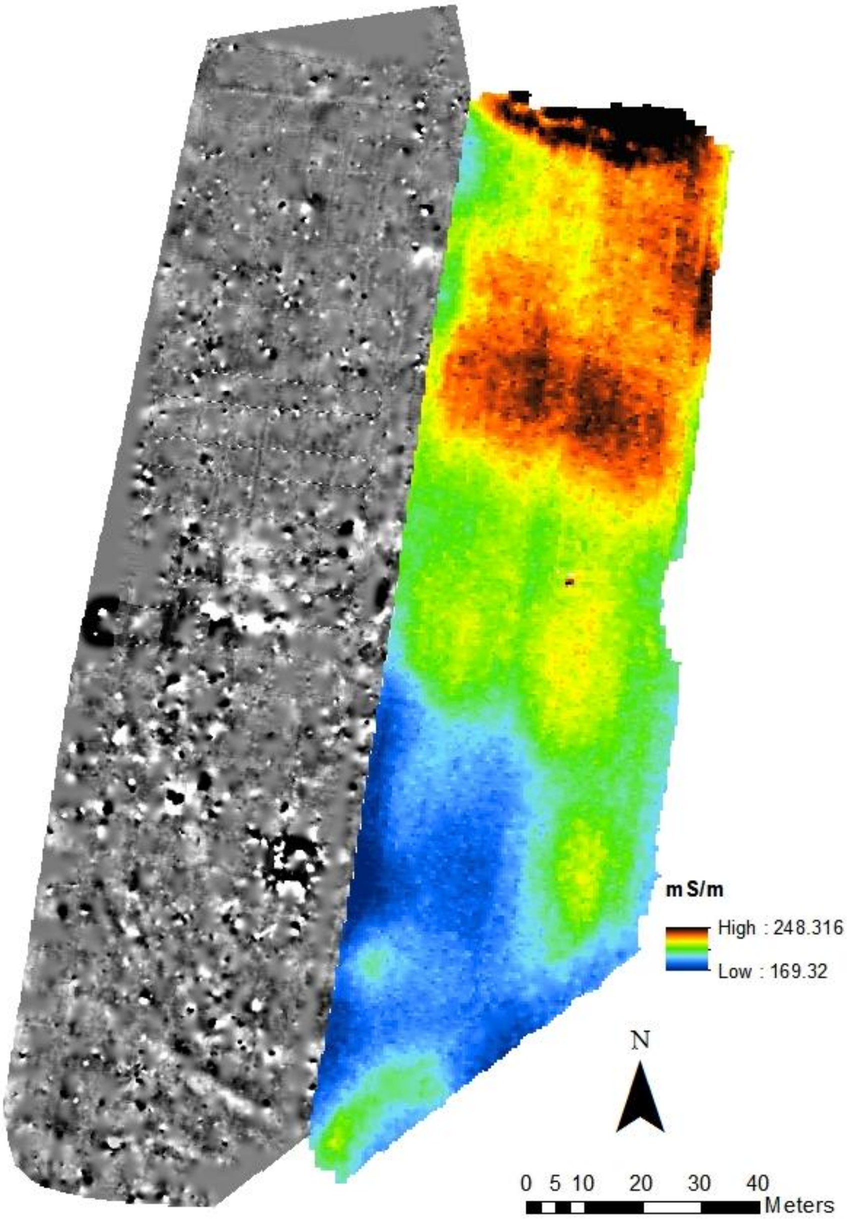


Figure 10: Electrical conductivity (GEM2, HCP configuration) for 0-2.5 m depth, with the map of the magnetic anomalies under the olive grove.

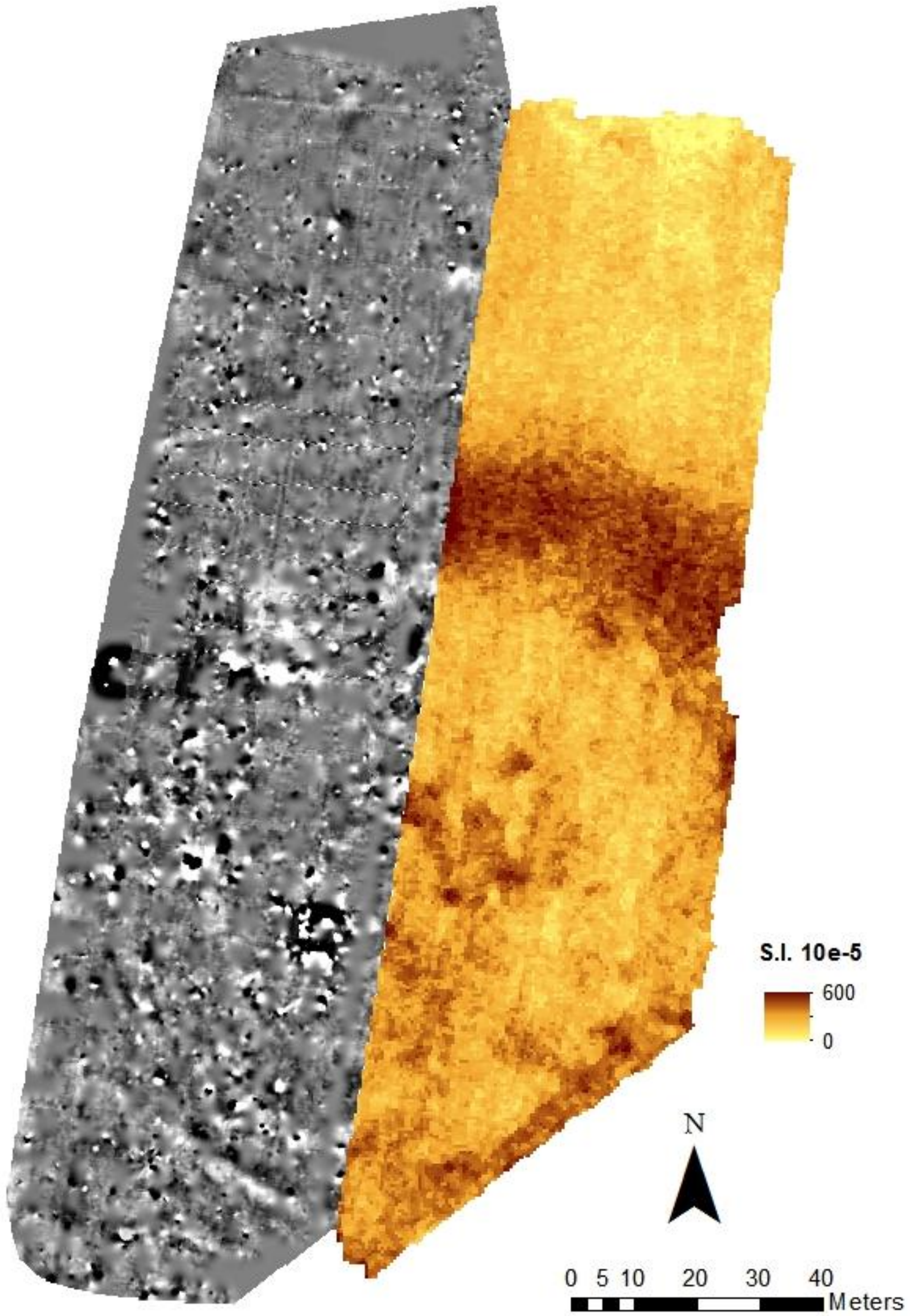


Figure 11: Magnetic susceptibility (GEM2, HCP configuration) for 0-1.7 m depth, with the map of the magnetic anomalies under the olive grove.

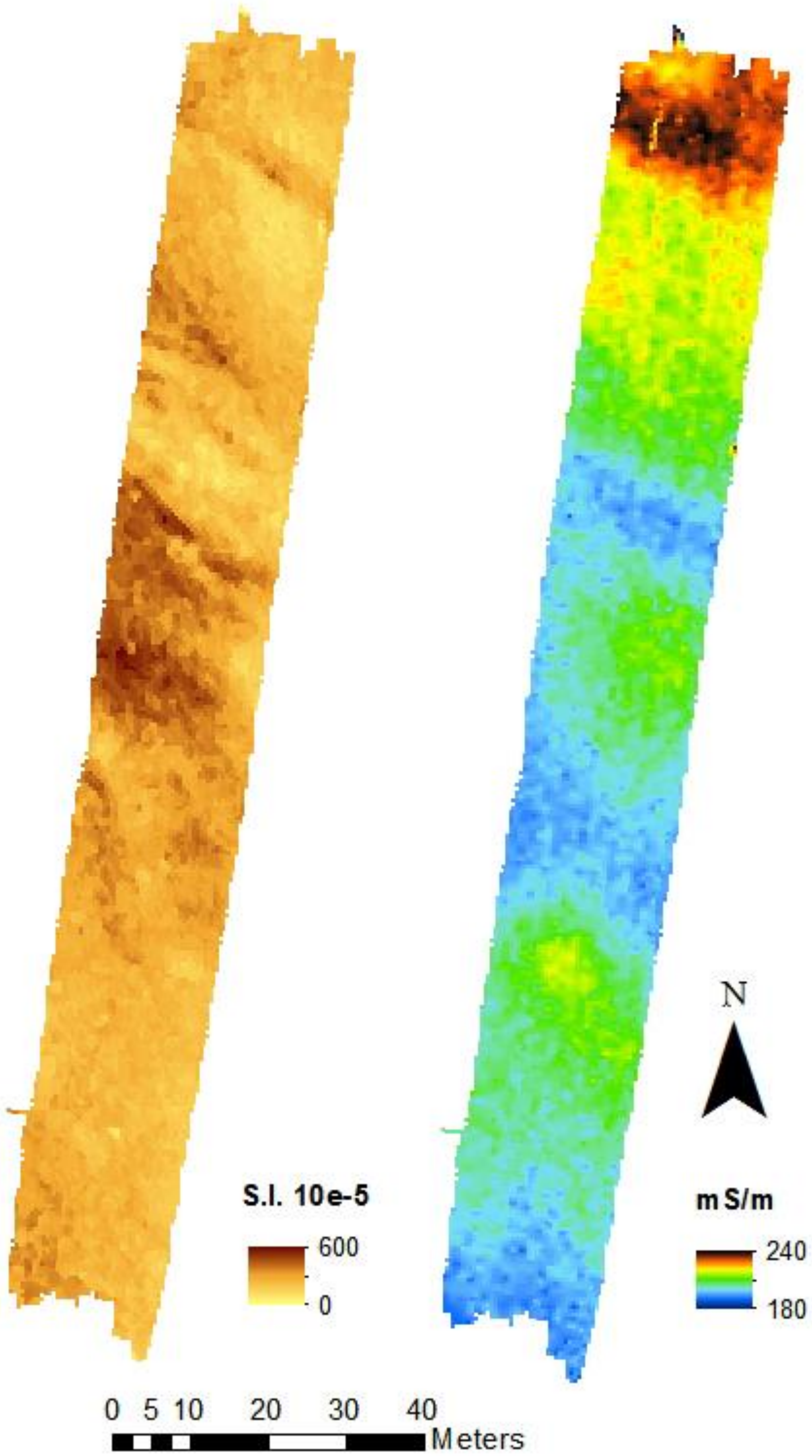


Figure 12: Electrical conductivity (GEM2, HCP configuration) for 0-2.5 m depth in the south part of the survey (left). Magnetic susceptibility (GEM2, HCP configuration) for 0-1.7 m depth in the south part of the survey (right).

Ground Penetrating Radar Survey

The GPR survey at Magoula Belitsi was completed within two different periods. The total area covered is 4275 m^2 and consisted of four grids. The grids were set on the center of the Neolithic settlement in accordance with the pottery distribution as indicated in Figure 13. A few more sections of the site were surveyd to the southern side of the magoula.

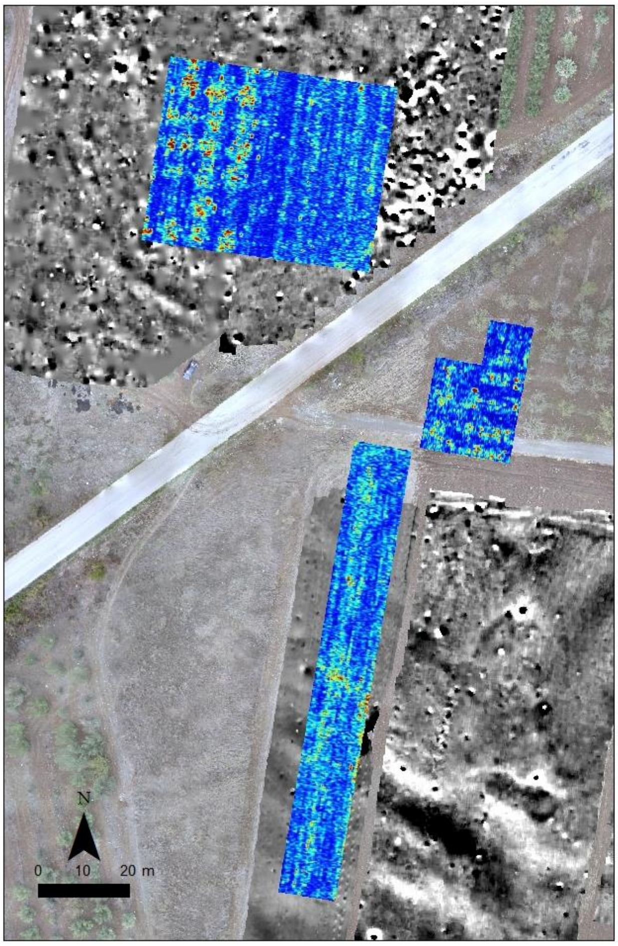
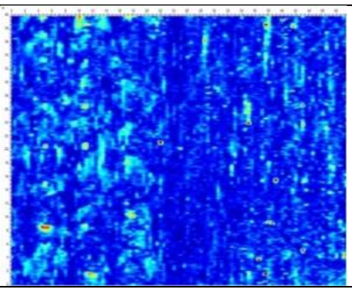
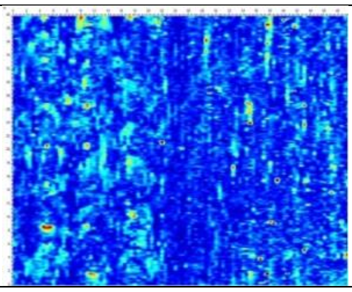
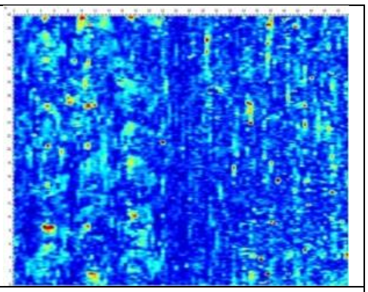
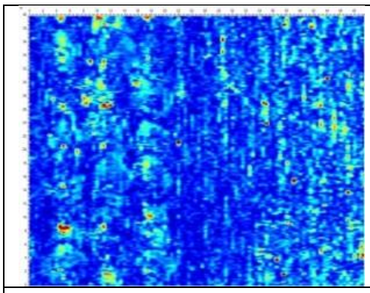
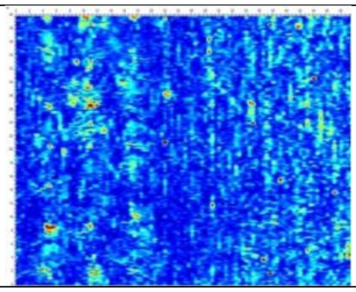
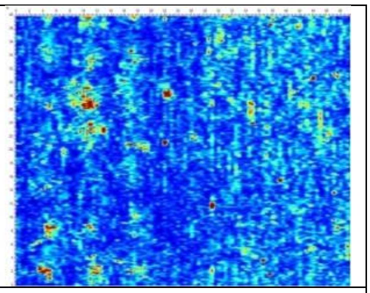
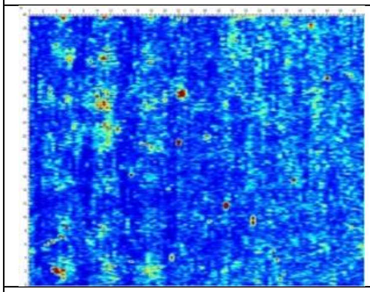
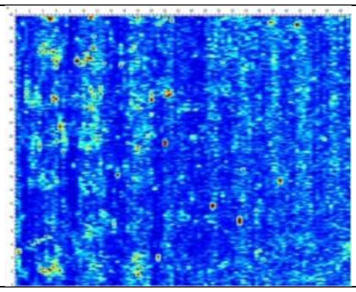
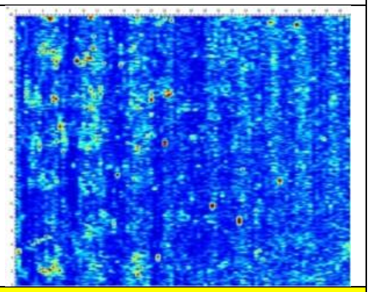


Figure 13: Area covered with GPR at Magoula Belitsi. The georeferenced slices are superimposed with the UAV image and the magnetic results.

The resulting slices for the grid at the top of the Magoula summarized in Table 1. The filters and corrections that applied are: Trace reposition, Repick first break (5%), Dewow, SEC2 (Atn=25 dB_m,StrtG=4.52,MaxG=650), Lowpass (f=50.0 % Nyquist), Highpass (f=30 % Nyquist), Background average subtraction.

		
0-10cm	10-20cm	20-30cm

		
30-40cm	40cm-50cm	50cm-60cm
		
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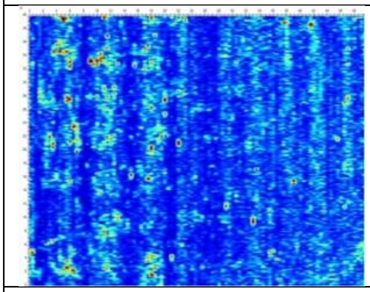	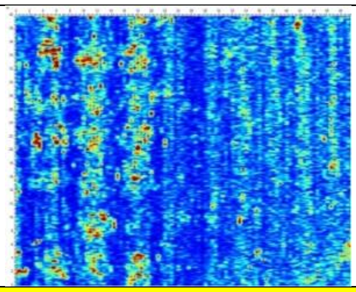	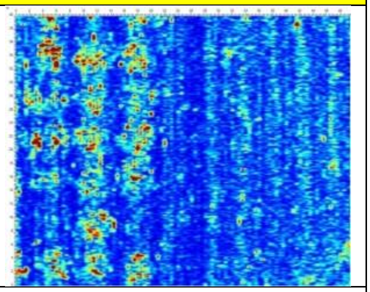
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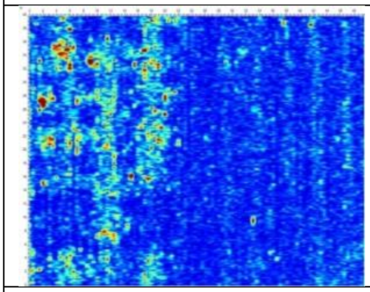
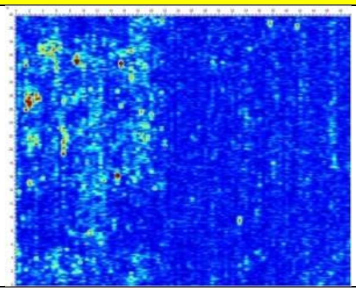
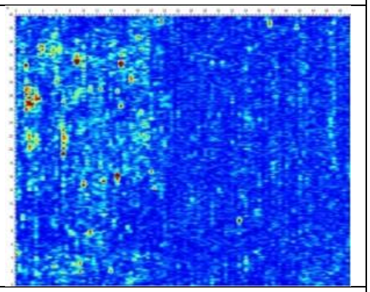
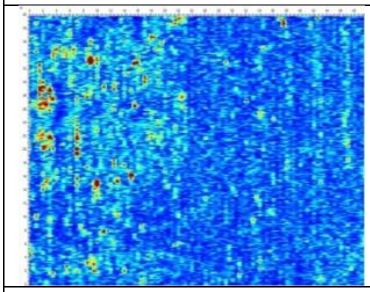
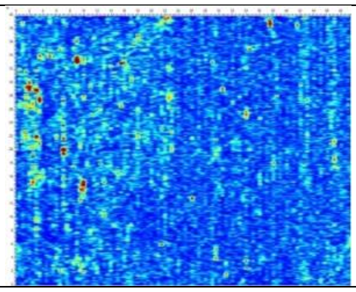
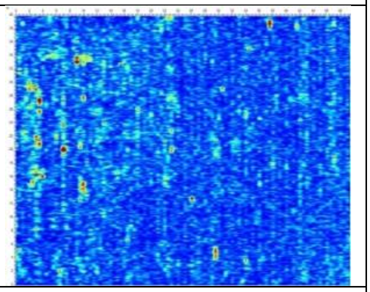
		
120cm-130cm	130cm-140cm	140cm-150cm
		
150cm-160cm	160cm-170cm	170cm-180cm

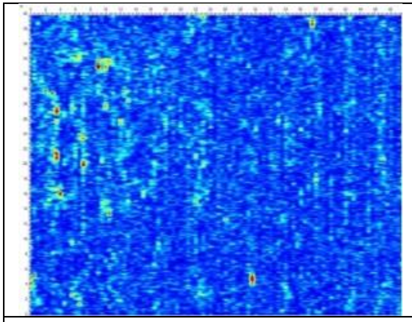
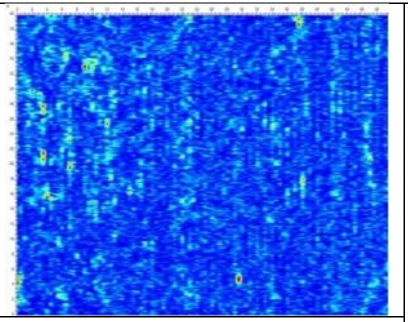
		
180cm-190cm	190cm-200cm	

Table 1: GPR depth slices for the grid with code name B9 (Phase 3) at Magoula Belitsi with 10cm thickness.

In contrast to the magnetic results, the GPR slices in this area do not show any reflection related to archaeological features. The strong reflections that appeared in the slice on Figure 14 were caused by trees on the surface and could not be removed through processing.

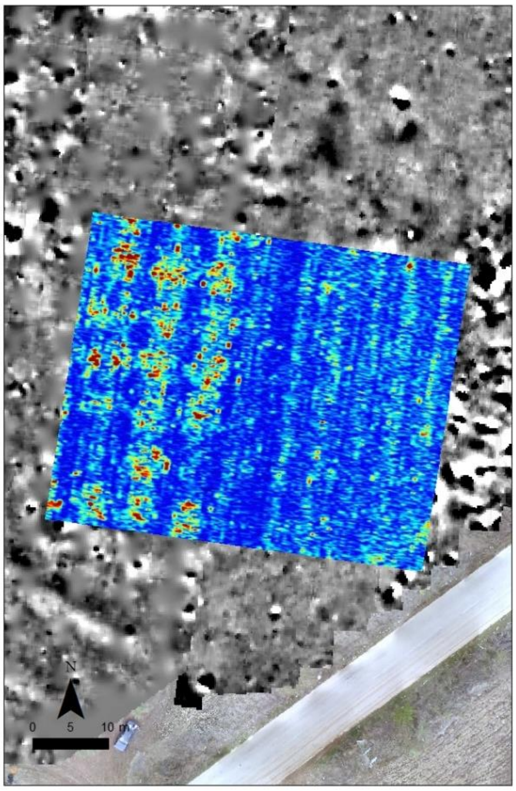
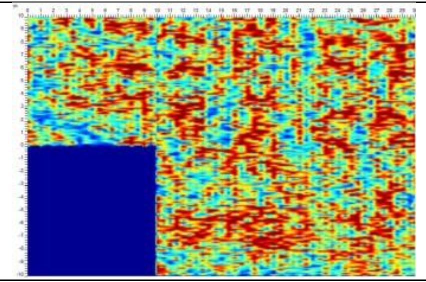
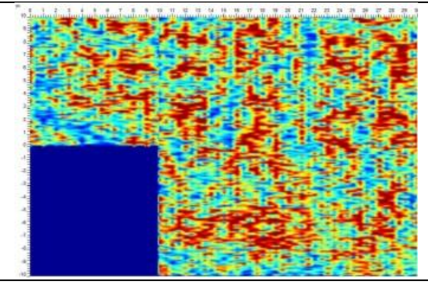


Figure 14: Georeferenced GPR slice at 100-110cm of the grid with code name B9, superimposed on the magnetic results.

Table 2 summarizes the slices for the grids with code names B1 and B5 and were set southwest of the settlement's center. The processing flow that was applied is: Trace reposition, Repick first break (5%), Dewow, Background average subtraction, Background subtraction (FW=1.0 m,Type=rectangular), Bandpass filter (Fc1=120 % Freq,Fp1=160 % Freq,Fp2=200 % Freq,Fc2=240 % Freq). The resulting slices exhibit similar issues as with the case of the grid B9. The strong anomalies show in all the produced slices are assigned to trees. Additionally, the signal attenuation is high; therefore no information could be acquired below 100 cm.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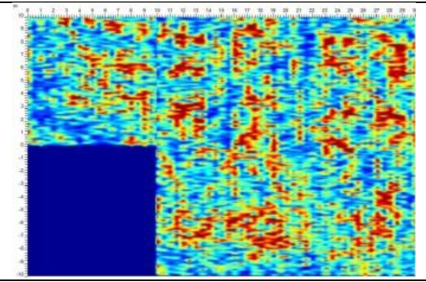
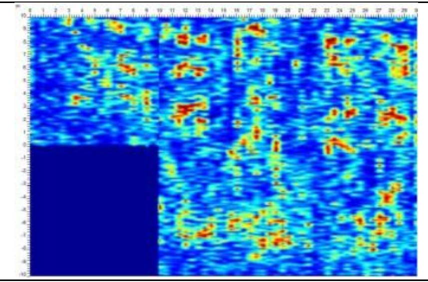
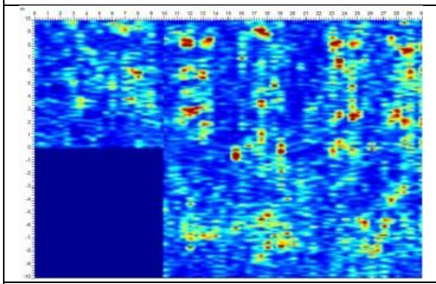
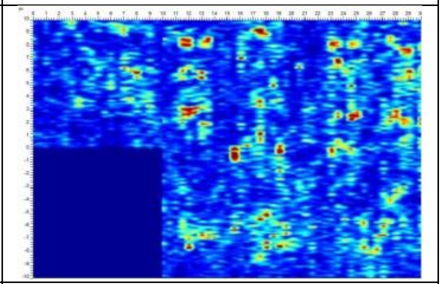
	
20-30cm	30-40cm
	
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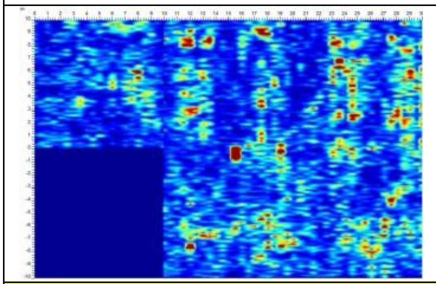	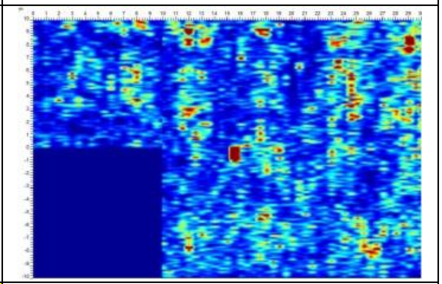
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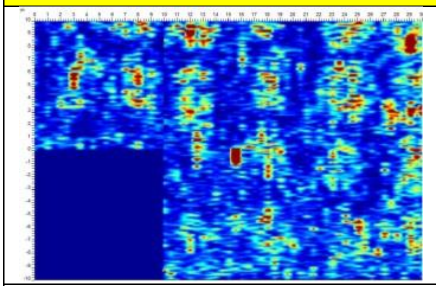	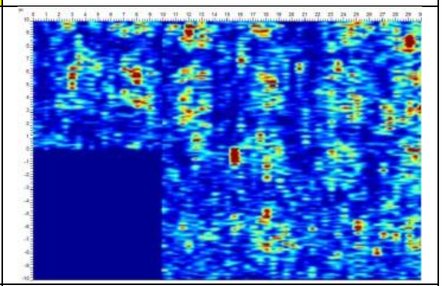
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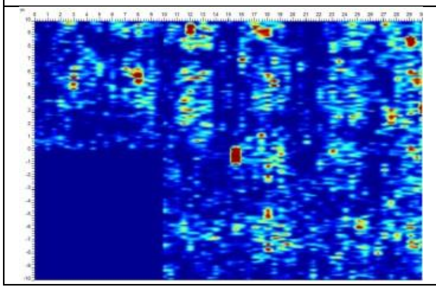	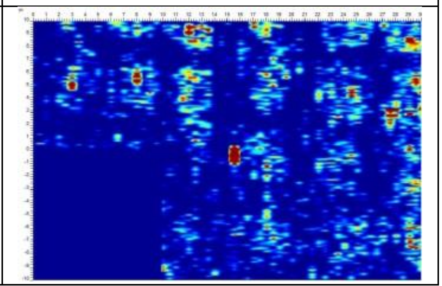

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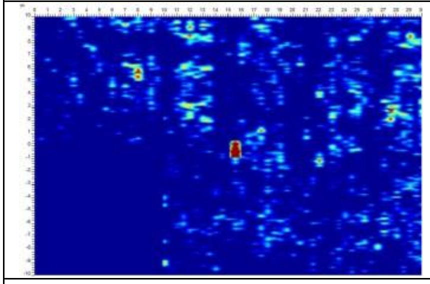	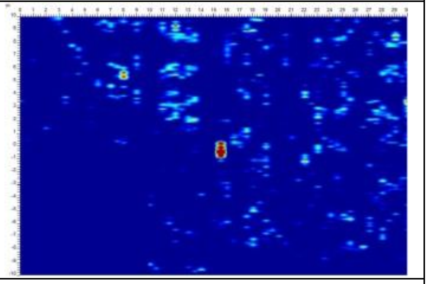
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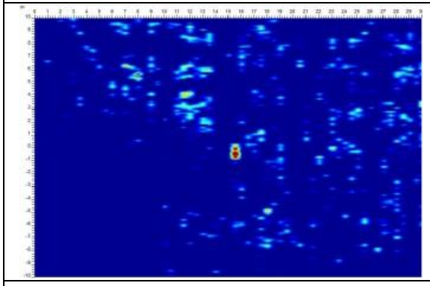
	
140cm-150cm	150cm-160cm

Table 2: GPR depth slices for the grids with codes name B1, B5 (Phase 3) at Magoula Belitsi with 10cm thickness.

Figure 15 presents the georeferenced slice at 60-70 cm where the anomalies caused by the trees are visible. This signature is noisy being caused by the tree trunks and roots. Their density makes the GPR signal interpretation extremely difficult and uncertain.

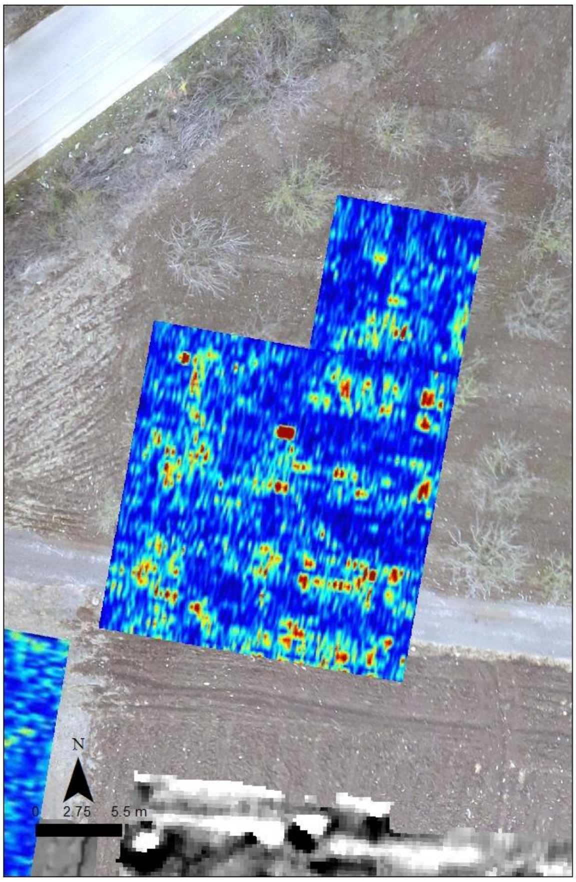
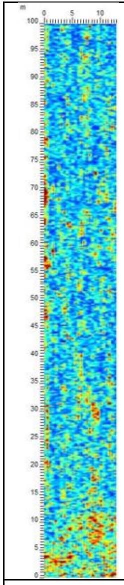
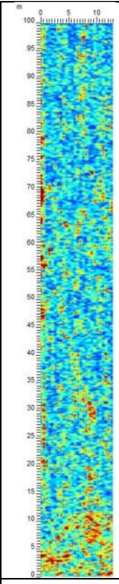
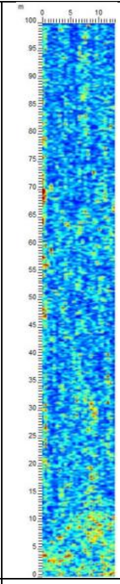
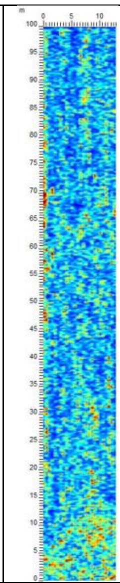
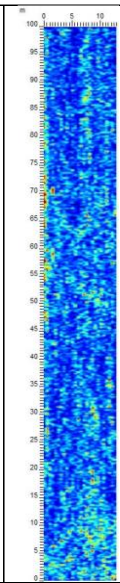
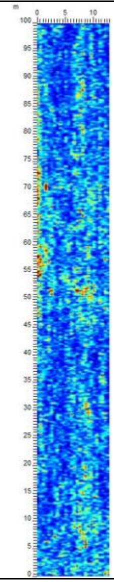
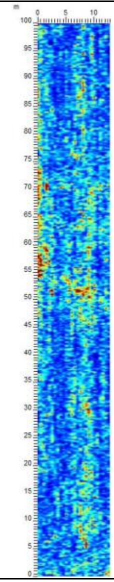
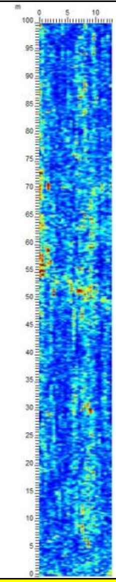
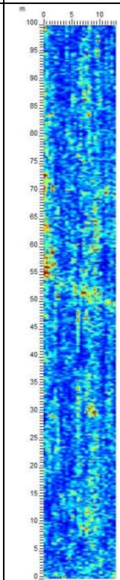
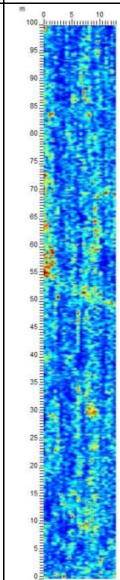


Figure 15: Georeferenced slice at 60-70cm for the grids with code names B1 and B5.

In Table 3, the resulting slices from the grid with code name Belitsi_GRID0 are presented. The filters and corrections that applied are: Trace reposition, Repick first break (20%), Dewow, SEC2 (Atn=25.19 dB_m,StrtG=2.53,MaxG=612) Background average subtraction, Bandpass filter (Fc1=40 % Freq,Fp1=80 % Freq,Fp2=160 % Freq,Fc2=200 % Freq), Background subtraction (FW=2 m,Type=rectangular). Overall, the resulting slices are noisy, with a few stronger anomalies of irregular shape.

				
0cm-10cm	10cm-20cm	20cm-30cm	30cm-40cm	40cm-50cm
				
50cm-60cm	60cm-70cm	70cm-80cm	80cm-90cm	90cm-100cm

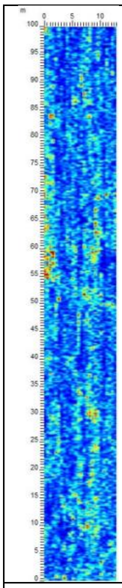
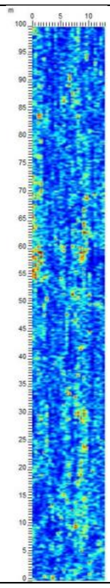
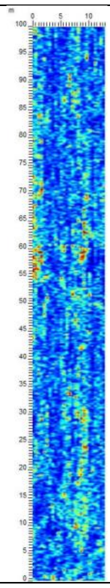
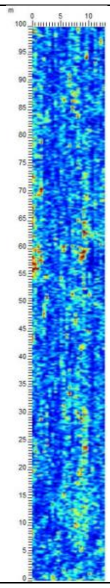
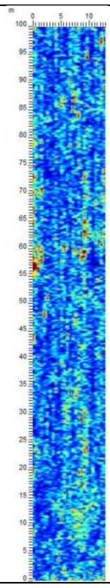
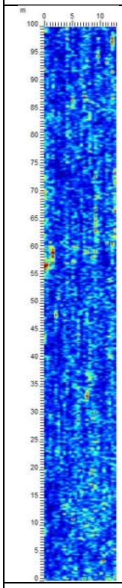
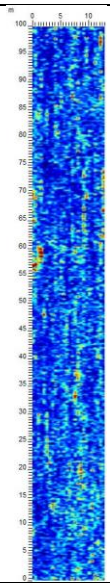
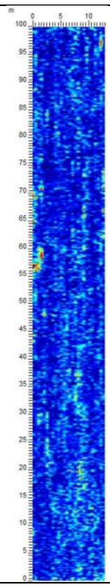
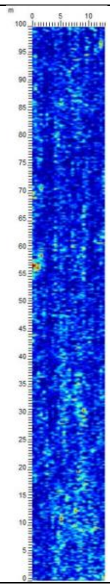
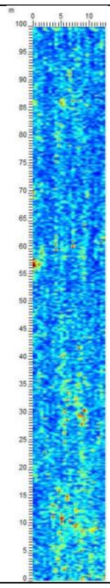
				
100cm-110cm	110cm-120cm	120cm-130cm	130cm-140cm	140cm-150cm
				
150cm-160cm	160cm-170m	170cm-180cm	180cm-190cm	190cm-200cm

Table 3: GPR depth slices for the grids with codes name Belitsi_GRID0 (Phase 1) at Magoula Belitsi with 10cm thickness.

Figure 16 shows the georeferenced slice at the depth of 70-80 cm from the surface and is superimposed on the magnetic results. Noise is visible either in stripes form that was caused from the rough surface or as weak amplitudes that appear irregularly all over the slice. The latter is probably caused by the saturated in water soil. Besides noise, an irregularly-shaped area of stronger amplitudes is identified on the center of the slice, thus is not clear what might be causing it. Considering the magnetic results, this certain area did not show any signatures that could be related with Neolithic features, thus these reflections shown in GPR slice could be related to geological features.

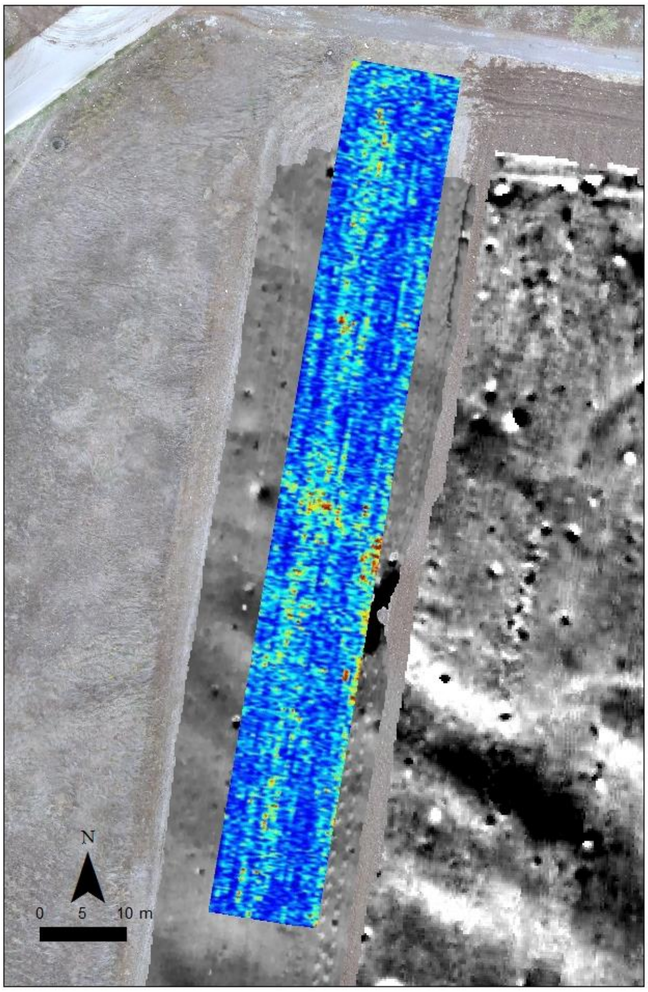


Figure 16: Georeferenced slice at 70-80cm superimposed on the magnetic results.

Vertical Electric Sounding

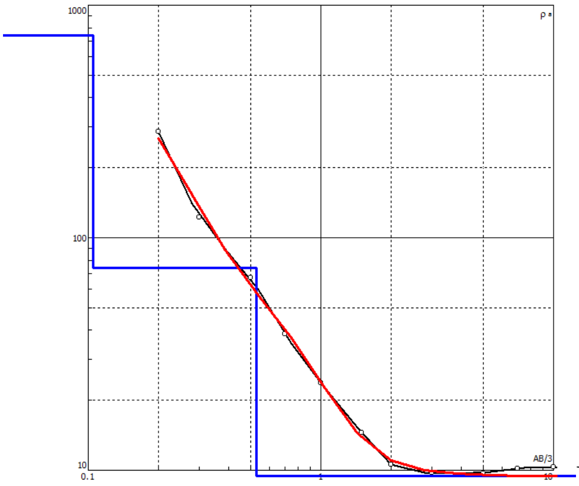


Figure 17: VES results from Belitsi

RMS =5.5 %	e1=0.105	e2=0.423
Rau1=741	Rau2=74.1	Rau3=9.42

VES shows a three layers model, with a very high resistivity (heterogeneous soils) on the top and a very low resistivity under 0.5 meters. This very low resistivity reveals clay medium. This very low resistivity could explain the difficulty related to GPR measurement.

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